APPENDIX B

SUMMARY OF STRENGTHENING TECHNIQUES

The deficiencies and alternative strengthening techniques discussed in Chapter 3 are summarized here as follows:

Table B1	Moment Resisting Systems Steel Moment Frames Concrete Moment Frames Moment Frames with Infill Walls Precast Concrete Moment Frames
Table B2	Shear Walls Reinforced Concrete or Reinforced Masonry Precast Concrete Unreinforced Masonry Shear Walls in Wood Frame Buildings
Table B3	Braced Frames
Table B4	Diaphragms
Table B5	Foundations
Table B6	Diaphragm to Vertical Element Connections
Table B7	Vertical Element to Foundation Connections

TABLE B1
MOMENT RESISTING SYSTEMS

STEEL MOMENT FRAMES	
Deficiency	**Strengthening Techniques**
Inadequate moment/shear capacity of beams, columns, or their connections	1. Increasing the moment capacity of the members and connections by adding cover plates or other steel sections to the flanges Or by boxing members. 2. Increasing the moment and shear capacity of the members and connections by providing steel gusset plates or knee braces. 3. Reducing the stresses in the existing frames by providing supplemental vertical-resisting elements (i.e., additional moment frames, braces, or shear walls) as discussed in Sec. 3.4. 4. Providing lateral bracing of unsupported flanges to increase capacity limited by tendency for lateral/torsional buckling. 5. Encasing the columns in concrete.
Inadequate beam/column panel zone capacity	1. Providing welded continuity plates between the column flanges. 2. Providing stiffener plates welded to the column flanges and web. 3. Providing web doubler plates at the column web. 4. Reducing the stresses in the panel zone by providing supplemental vertical-resisting elements (i.e., additional moment frames, braces, or shear walls) as discussed in Sec. 3.4.
Excessive drift	1. Increasing the capacity and, hence, the stiffness of the existing moment frame by cover plates or boxing. 2. Increasing the stiffness of the beams and columns at their connections by providing steel gusset plates to form haunches. 3. Reducing the drift by providing supplemental vertical-resisting elements (i.e., additional moment frames, braces, or shear walls) as discussed in Sec. 3.4. 4. Increasing the stiffness by encasing columns in reinforced concrete. 5. Reducing the drift by adding supplemental damping as discussed in Sec. 4.
CONCRETE MOMENT FRAMES	
Inadequate ductile bending or shear capacity in the beams or columns and lack of confinement, frequently in the joints	1. Increasing the ductility and capacity by jacketing the beam and column joints or increasing the beam or column capacities. 2. Reducing the seismic stresses in the existing frames by providing supplemental vertical-resisting elements (i.e., additional moment frames, braces, or shear walls) as discussed in Sec. 3.4. 3. Changing the system to a shear wall system by infilling the reinforced concrete frames with reinforced concrete.

TABLE B1--continued

MOMENT FRAMES WITH INFILL WALLS	
Crushing of the infill at the upper and lower corners due to the diagonal compression strut type action of the infill wall	1. Eliminating the hazardous effects of the infill by providing a gap between the infill and the frame and providing out-of-plane support. 2. Treating the infill frame as a shear wall and correcting the deficiencies as described in Sec. 3.2.
Shear failure of the beam/column connection in the steel frames or direct shear transfer failure of the beam or column in concrete frames	
Tensile failure of the columns or their connections due to the uplift forces resulting from the braced frame action induced by the infill	
Splitting of the infill due to the orthogonal tensile stresses developed in the diagonal compressive strut	
Loss of infill by out-of-plane forces due to loss of anchorage or excessive slenderness of the infill wall	
PRECAST CONCRETE MOMENT FRAMES	
Inadequate capacity and/or ductility of the joints between the precast units	1. Removing existing concrete in the precast elements to expose the existing reinforcing steel, providing additional reinforcing steel welded to the existing steel (or drilled and grouted), and replacing the removed concrete with cast-in-place concrete. 2. Reducing the forces on the connections by providing supplemental vertical-resisting elements (i.e., additional moment frames, braces, or shear walls) as discussed in Sec. 3.4.

TABLE B2
SHEAR WALLS

REINFORCED CONCRETE OR REINFORCED MASONRY SHEAR WALLS	
Deficiency	**Strengthening Techniques**
Inadequate shear capacity	1. Increasing the effectiveness of the existing walls by filling in door or window openings with reinforced concrete or masonry. 2. Providing additional thickness to the existing walls with a poured-in-place or pneumatically applied (i.e., shotcrete) reinforced concrete overlay anchored to the inside or outside face of the existing walls. 3. Reducing the shear or flexural stresses in the existing walls by providing supplemental vertical-resisting elements (i.e., shear walls, braces, or external buttresses) as discussed in Sec. 3.4.
Inadequate flexural capacity	1. Increasing the effectiveness of the existing walls by filling in door or window openings with reinforced concrete or masonry. 2. Providing additional thickness to the existing walls with a poured-in-place or pneumatically applied (i.e., shotcrete) reinforced concrete overlay anchored to the inside or outside face of the existing walls. 3. Reducing the shear or flexural stresses in the existing walls by providing supplemental vertical-resisting elements (i.e., shear walls, braces, or external buttresses) as discussed in Sec. 3.4.
Inadequate shear or flexural capacity in the coupling beams between shear walls or piers	1. Eliminating the coupling beams by filling in openings with reinforced concrete. 2. Removing the existing beams and replacing with new stronger reinforced beams. 3. Adding reinforced concrete to one or both faces of the wall and providing an additional thickness to the existing wall. 4. Reducing the shear or flexural stresses in the connecting beams by providing additional vertical-resisting elements (i.e., shear walls, braces, or external buttresses) as discussed in Sec. 3.4.
PRECAST CONCRETE SHEAR WALLS	
Inadequate shear or flexural capacity in the wall panels	1. Increasing the shear and flexural capacity of walls with significant openings for doors or windows by infilling the existing openings with reinforced concrete. 2. Increasing the shear or flexural capacity by adding reinforced concrete (poured-in-place or shotcrete) at the inside or outside face of the existing walls. 3. Adding interior shear walls to reduce the flexural or shear stress in the existing precast panels.

TABLE B2--continued

PRECAST CONCRETE SHEAR WALLS--continued	
Inadequate interpanel shear or flexural capacity	1. Making each panel act as a cantilever to resist in-plane forces (by adding or strengthening tie-downs, edge reinforcement, footings). 2. Providing a continuous wall by exposing the reinforcing steel in the edges of adjacent units, adding ties, and repairing with concrete.
Inadequate out-of-plane flexural capacity	1. Providing pilasters at and/or between the interpanel joints. 2. Adding horizontal beams between the columns or pilasters at mid-height of the wall.
Inadequate shear or flexural capacity in coupling beams	1. Eliminating the coupling beams by filling in openings with reinforced concrete. 2. Removing the existing beams and replacing with new stronger reinforced beams. 3. Adding reinforced concrete to one or both faces of the wall and providing an additional thickness to the existing wall. 4. Reducing the shear or flexural stresses in the connecting beams by providing additional vertical-resisting elements (i.e., shear walls, braces, or external buttresses) as discussed in Sec. 3.4.2
UNREINFORCED MASONRY SHEAR WALLS	
Inadequate in-plane shear and out-of-plane flexural capacity of the walls	1. Providing additional shear capacity by placing reinforcing steel on the inside or outside face of the wall and applying new reinforced concrete. 2. Providing additional capacity for out-of-plane lateral forces by adding reinforcing steel to the wall utilizing the center coring technique. 3. Providing additional capacity for out-of-plane lateral forces by adding thin surface treatments (e.g., plaster with wire mesh and portland cement mortar) at the inside and outside faces of existing walls. 4. Filling in existing window or door openings with reinforced concrete. 5. Providing additional shear walls at the interior or perimeter of the building or providing external buttresses.
Inadequate shear capacity of the coupling beam	1. Filling in openings with reinforced concrete. 2. Removing existing connecting beams and replacing them with properly designed new reinforced concrete beams. 3. Providing additional shear walls at interior or perimeter of building or external buttresses.

TABLE B2--continued

SHEAR WALLS IN WOOD FRAME BUILDINGS	
Inadequate shear capacity of the wall	1. Increasing the shear capacity by providing additional nailing to the existing finish material. 2. Increasing the shear capacity by adding plywood sheathing to one or both sides of the wall. 3. Reducing the loads on the wall by providing supplemental shear walls to the interior or perimeter of the building.
Inadequate uplift or hold-down capacity of the wall	1. Increasing the tensile capacity of the connections at the edge of the shear walls by providing metal connectors. 2. Reducing the overturning moments by providing supplemental vertical-resisting elements as discussed in Sec. 3.4.

TABLE B3
BRACED FRAMES

STEEL CONCENTRICALLY BRACED FRAMES (including chevron or K-bracing)	
Deficiency	**Strengthening Techniques**
Inadequate lateral force capacity of the bracing system governed by buckling of the compression brace	1. Increasing the capacity of the braces by adding new members thus increasing the area and reducing the radius of gyration of the braces. 2. Increasing the capacity of the member by reducing the unbraced length of the existing member by providing secondary braces. 3. Providing greater capacity by removing and replacing the existing members with new members of greater capacity. 4. Reducing the loads on the braces by providing supplemental vertical-resisting elements (i.e., shear walls, braces, or eccentric bracing) as discussed in Sec. 3.4.
Inadequate capacity of the brace connection	1. Increasing the capacity of the connections by additional bolting or welding. 2. Increasing the capacity of the connections by removing and replacing the connection with members of greater capacity. 3. Reducing the loads on the braces and their connections by providing supplemental vertical-resisting elements (i.e., shear walls, braces, or eccentric bracing) as discussed in Sec. 3.4.
Inadequate axial load capacity in the columns or beams of the bracing system	1. Providing additional axial load capacity by adding cover plates to the member flanges or by boxing the flanges. 2. Providing additional axial load capacity by jacketing the existing members with reinforced concrete. 3. Reducing the loads on the beams and columns by providing supplemental vertical-resisting elements (i.e., shear walls, braces, or eccentric bracing) as discussed in Sec. 3.4.

TABLE B3--continued

ROD OR OTHER TENSION BRACING	
Inadequate tension capacity of the rod, tensile member, or its connection	1. Increasing the capacity by strengthening the existing tension members. 2. Increasing the capacity by removing the existing tension members and replacing with new members of greater capacity. 3. Increasing the capacity by removing the existing tension member and replacing it with diagonal or X-bracing capable of resisting compression as well as tension forces. 4. Reducing the forces on the existing tension members by providing supplemental vertical-resisting elements (i.e., additional tension rods) as discussed in Sec. 3.4.
Inadequate axial capacity of the beams or columns in the bracing system	1. Increasing the axial capacity by adding cover plates to the existing flanges or by boxing the existing flanges. 2. Reducing the forces on the existing columns or beams by providing supplemental vertical-resisting elements (i.e., braced frames or shear walls) as discussed in Sec. 3.4.
ECCENTRIC BRACING	
Nonconformance with current design standards	1. Ensuring that the system is balanced (i.e., there is a link beam at one end of each brace), the brace and the connections are designed to develop shear or flexural yielding in the link, the connection is a full moment connection, where the link beam has an end at a column, and lateral bracing is provided to prevent out-of-plane beam displacements that would compromise the intended action. 2. Providing supplemental vertical-resisting elements such as additional eccentric braced frames.

TABLE B4
DIAPHRAGMS

TIMBER DIAPHRAGMS (straight-laid or diagonal sheathing or plywood)	
Deficiency	**Strengthening Techniques**
Inadequate shear capacity of the diaphragm	1. Increasing the capacity of the existing timber diaphragm by providing additional nails or staples with due regard for wood splitting problems. 2. Increasing the capacity of the existing timber diaphragm by means of a new plywood overlay. 3. Reducing the diaphragm span through the addition of supplemental vertical-resisting elements (i.e., shear wall or braced frames) as discussed in Sec. 3.4.
Inadequate chord capacity of the diaphragm	1. Providing adequate nailed or bolted continuity splices along joists or fascia parallel to the chord. 2. Providing a new continuous steel chord member along the top of the diaphragm. 3. Reducing the stresses on the existing chords by reducing the diaphragms, span through the addition of new shear walls or braced frames as discussed in Sec. 3.4.
Excessive shear stresses at diaphragm openings or at plan irregularities	1. Reducing the local stresses by distributing the forces along the diaphragm by means of drag struts. 2. Increasing the capacity of the diaphragm by overlaying the existing diaphragm with plywood and nailing the plywood through the sheathing at the perimeter of the sheets adjacent to the opening or irregularity. 3. Reducing the diaphragm stresses by reducing the diaphragm spans through the addition of supplemental shear walls or braced frames as discussed in Sec. 3.4.
Inadequate stiffness of the diaphragm resulting in excessive diaphragm deformations	1. Increasing the stiffness of the diaphragm by the addition of a new plywood overlay. 2. Reducing the diaphragm span and hence reducing the displacements by providing new supplemental vertical-resisting elements such as shear walls or braced frames as discussed in Sec. 3.4.
CONCRETE DIAPHRAGMS (monolithic concrete diaphragms--i.e., reinforced concrete or post-tensioned concrete)	
Inadequate in-plane shear capacity of the concrete diaphragm	1. Increasing the shear capacity by overlaying the existing concrete diaphragm with a new reinforced concrete topping slab. 2. Reducing the shear in the existing concrete diaphragm by providing supplemental vertical-resisting elements (i.e., shear walls or braced frames) as discussed in Sec. 3.4.

TABLE B4--continued

Inadequate diaphragm chord capacity	1. Increasing the flexural capacity by removing the edge of the diaphragm slab and casting a new chord member integral with the slab. 2. Adding a new chord member by providing a new reinforced concrete or steel member above or below the slab and connecting the new member to the existing slab with drilled and grouted dowels or bolts as discussed in Sec. 3.5.4.3. 3. Reducing the existing flexural stresses by providing supplemental vertical-resisting elements (i.e., shear walls or braced frames) as discussed in Sec. 3.4.
Excessive shear stresses at the diaphragm openings or plan irregularities	1. Reducing the local stresses by distributing the forces along the diaphragm by means of structural steel or reinforced concrete elements cast beneath the slab and made integral through the use of drilled and grouted dowels. 2. Increasing the capacity of the concrete by providing a new concrete topping slab in the vicinity of the opening and reinforcing with trim bars. 3. Removing the stress concentration by filling in the diaphragm opening with reinforced concrete. 4. Reducing the shear stresses at the location of the openings by adding supplemental vertical-resisting elements (i.e., shear walls or braced frames) as discussed in Sec. 3.4.

TABLE B4--continued

POOURED GYPSUM DIAPHRAGMS	
Inadequate in-plane shear capacity of the concrete diaphragm	1. Increasing the shear capacity by overlaying the existing concrete diaphragm with a new reinforced concrete topping slab. 2. Reducing the shear in the existing concrete diaphragm by providing supplemental vertical-resisting elements (i.e., shear walls or braced frames) as discussed in Sec. 3.4. 3. Increasing the flexural capacity by removing the edge of the diaphragm slab and casting a new chord member integral with the slab.
Inadequate diaphragm chord capacity	4. Adding a new chord member by providing a new reinforced concrete or steel member above or below the slab and connecting the new member to the existing slab with drilled and grouted dowels or bolts as discussed in Sec. 3.5.4.3. 5. Reducing the existing flexural stresses by providing supplemental vertical-resisting elements (i.e., shear walls or braced frames) as discussed in Sec. 3.4. 6. Reducing the local stresses by distributing the forces along the diaphragm by means of structural steel or reinforced concrete elements cast beneath the slab and made integral through the use of drilled and grouted dowels.
Excessive shear stresses at the diaphragm openings or plan irregularities	7. Increasing the capacity of the concrete by providing a new concrete topping slab in the vicinity of the opening and reinforcing with trim bars. 8. Removing the stress concentration by filling in the diaphragm opening with reinforced concrete. 9. Reducing the shear stresses at the location of the openings by adding supplemental vertical-resisting elements (i.e., shear walls or braced frames) as discussed in Sec. 3.4. 10. Adding a new horizontal bracing system may be the most effective strengthening alternative.
PRECAST CONCRETE DIAPHRAGMS (precast or post-tensioned concrete planks, tees, or cored slabs)	
Inadequate in-plane shear capacity of the connections between the adjacent units	1. Replacing and increasing the capacity of the existing connections by overlaying the existing diaphragm with a new reinforced concrete topping slab. 2. Reducing the shear forces on the diaphragm by providing supplemental vertical-resisting elements (i.e., shear walls or braced frames) as discussed in Sec. 3.4.
Inadequate diaphragm chord capacity	1. Providing a new continuous steel member above or below the steel slab and connecting the new member to the existing slab with bolts. 2. Removing the edge of the diaphragm and casting a new chord member integral with the slab. 3. Reducing the diaphragm chord forces by providing supplemental vertical-resisting elements (i.e., shear walls or braced frames) as discussed in Sec. 3.4.

TABLE B4--continued

PRECAST CONCRETE DIAPHRAGMS--continued	
Excessive in-plane shear stresses at diaphragm openings or plan irregularities	1. Reducing the local stresses by distributing the forces along the diaphragm by means of concrete drag struts cast beneath the slab and made integral with the existing slab with drilled and grouted dowels. 2. Increasing the capacity by overlaying the existing slab with a new reinforced concrete topping slab with reinforcing trim bars in the vicinity of the opening. 3. Removing the stress concentration by filling in the diaphragm opening with reinforced concrete. 4. Reducing the shear stresses at the location of the openings by providing supplemental vertical-resisting elements (i.e., shear walls or braced frames) as discussed in Sec. 3.4.
STEEL DECK DIAPHRAGMS (steel decking on steel framing)	
Inadequate in-plane shear capacity which may be governed by the capacity of the welding to the supports or the capacity of the seam welds between the deck units	1. Increasing the steel deck shear capacity by providing additional welding. 2. Increasing the deck shear capacity of unfilled steel decks by adding a reinforced concrete fill or overlaying with concrete filled steel decks a new topping slab. 3. Increasing the diaphragm shear capacity by providing a new horizontal steel bracing system under the existing diaphragm. 4. Reducing the diaphragm shear stresses by providing supplemental vertical-resisting elements to reduce the diaphragm span as discussed in Sec. 3.4.
Inadequate diaphragm chord capacity	1. Increasing the chord capacity by providing welded or bolted continuity splices in the perimeter chord steel framing members. 2. Increasing the chord capacity by providing a new continuous steel member on top or bottom of the diaphragm. 3. Reducing the diaphragm chord stresses by providing supplemental vertical-resisting elements (i.e., shear walls or braced frames) such that the diaphragm span is reduced as discussed in Sec. 3.4.
Excessive in-plane shear stresses at diaphragm openings or plan irregularities	1. Reducing the local stress concentrations by distributing the forces into the diaphragm by means of steel drag struts. 2. Increasing the capacity of the diaphragm by reinforcing the edge of the opening with a steel angle frame welded to the decking. 3. Reducing the diaphragm stresses by providing supplemental vertical-resisting elements (i.e., shear walls, braced frames or new moment frames) such that the diaphragm span is reduced as discussed in Sec. 3.4.

TABLE B4--continued

HORIZONTAL STEEL BRACING	
Inadequate force capacity of the members (i.e., bracing and floor or roof beams) and/or the connections	1. Increasing the capacity of the existing bracing members or removing and replacing them with new members and connections of greater capacity. 2. Increasing the capacity of the existing members by reducing unbraced lengths. 3. Increasing the capacity of the bracing system by adding new horizontal bracing members to previously unbraced panels (if feasible). 4. Increasing the capacity of the bracing system by adding a steel deck diaphragm to the floor system above the steel bracing. 5. Reducing the stresses in the horizontal bracing system by providing supplemental vertical-resisting elements (i.e., shear walls or braced frames) as discussed in Sec. 3.4.

TABLE B5
FOUNDATIONS

CONTINUOUS OR STRIP WALL FOOTINGS	
Deficiency	**Strengthening Techniques**
Excessive soil bearing pressure due to overturning forces	1. Increasing the bearing capacity of the footing by underpinning the footing ends and providing additional footing area. 2. Increasing the vertical capacity of the footing by adding new drilled piers adjacent and connected to the existing footing. 3. Increasing the soil bearing capacity by modifying the existing soil properties. 4. Reducing the overturning forces by providing supplemental vertical-resisting elements (i.e., shear walls or braced frames) as discussed in Sec. 3.4.
Excessive uplift conditions due to overturning forces	1. Increasing the uplift capacity of the existing footing by adding drilled piers or soil anchors. 2. Increasing the size of the existing footing by underpinning to mobilize additional foundation and reduce soil pressures. 3. Reducing the uplift forces by providing supplemental vertical-resisting elements (i.e., shear walls or braced frames) as discussed in Sec. 3.4.
INDIVIDUAL PIER OR COLUMN FOOTINGS	
Excessive soil bearing pressure due to overturning forces	1. Increasing the bearing capacity of the footing by underpinning the footing ends and providing additional footing area. 2. Increasing the vertical capacity of the footing by adding new drilled piers adjacent and connected to the existing footing. 3. Reducing the bearing pressure on the existing footings by connecting adjacent footings with deep reinforced concrete tie beams. 4. Increasing the soil bearing capacity by modifying the existing soil properties. 5. Reducing the overturning forces by providing supplemental vertical-resisting elements (i.e., shear walls or braced frames).
Excessive uplift conditions due to overturning forces	1. Increasing the uplift capacity of the existing footing by adding drilled piers or soil anchors. 2. Increasing the size of the existing footing by underpinning to mobilize additional foundation and soil weight. 3. Increasing the uplift capacity by providing a new deep reinforced concrete beam to mobilize the dead load on an adjacent footing. 4. Reducing the uplift forces by providing supplemental vertical-resisting elements (i.e., shear walls or braced frames).

TABLE B5--continued

INDIVIDUAL PIER OR COLUMN FOOTINGS--continued	
Inadequate passive soil pressure to resist lateral loads	1. Providing an increase in bearing area by underpinning and enlarging the footing. 2. Providing an increase in bearing area by adding new tie beams between existing footings. 3. Improving the existing soil conditions adjacent to the footing to increase the allowable passive pressure. 4. Reducing the bearing pressure at overstressed locations by providing supplemental vertical-resisting elements such as shear walls or braced frames as discussed in Sec. 3.4.
PILES OR DRILLED PIERS	
Excessive tensile or compressive loads on the piles or piers due to the seismic forces combined with the gravity loads	1. Increasing the capacity of the foundation by removing the existing pile cap, driving additional piles and providing new pile caps of larger size. 2. Reducing the loads on overstressed pile caps by adding tie beams to adjacent pile caps and distributing the loads.
Inadequate lateral force capacity to transfer the seismic shears from the pile caps and the piles to the soil	1. Reducing the loads on overstressed pile caps by adding tie beams to adjacent pile caps and distributing the loads. 2. Increasing the allowable passive pressure of the soil by improving the soil adjacent to the pile cap. 3. Increasing the capacity of the foundation by removing the existing pile cap, driving additional piles, and providing new pile caps of larger size. 4. Reducing loads on the piles or piers by providing supplemental vertical-resisting elements (i.e., braced frames or shear walls) and transferring forces to other foundation members with reserve capacity as discussed in Sec. 3.4.
MAT	
Inadequate moment capacity to resist combined gravity plus seismic overturning forces	1. Increasing the mat capacity locally by providing additional reinforced concrete (i.e., an inverted column capital) doweled and bonded to the existing mat to act as a monolithic section. 2. Providing new shear walls above the mat to distribute the overturning loads and also to locally increase the section modulus of the mat.
Inadequate passive soil pressure to resist sliding	1. Constructing properly spaced shear keys at the mat perimeter.

TABLE B6
DIAPHRAGM TO VERTICAL ELEMENT CONNECTIONS

CONNECTIONS OF TIMBER DIAPHRAGMS	
Deficiency	**Strengthening Techniques**
Inadequate capacity to transfer in-plane shear at the connection of the diaphragm to interior shear walls or vertical bracing	1. Increasing the shear transfer capacity of the diaphragm local to the connection by providing additional nailing to existing or new blocking. 2. Reducing the local shear transfer stresses by distributing the forces from the diaphragm by providing a collector member to transfer the diaphragm forces to the shear wall. 3. Reducing the shear transfer stress in the existing connection by providing supplemental vertical-resisting elements as discussed in Sec. 3.4.
Inadequate capacity to transfer in-plane shear at the connection of the diaphragm to exterior shear walls or vertical bracing	1. Increasing the capacity of existing connections by providing additional nailing and/or bolting. 2. Reducing the local shear transfer stresses by distributing the forces from the diaphragm by providing chords or collector members to collect and distribute shear from the diaphragm to the shear wall or bracing. 3. Reducing the shear stress in the existing connection by providing supplemental vertical-resisting elements as discussed in Sec. 3.4.
Inadequate out-of-plane anchorage at the connection of the diaphragm to exterior concrete or masonry walls	1. Increasing the capacity of the connection by providing steel straps connected to the wall (using drilled and grouted bolts or through bolts for masonry walls) and bolted or lagged to the diaphragm or roof or floor joists. 2. Increasing the capacity of the connections by providing a steel anchor to connect the roof or floor joists to the walls. 3. Increasing the redundancy of the connection by providing continuity ties into the diaphragm.
Inadequate tensile capacity between floors due to overturning moments	1. Increasing the tensile capacity of the connections at the edge of the shear walls by providing metal connectors. 2. Reducing the overturning moments by providing supplemental vertical-resisting elements as discussed in Sec. 3.4.

TABLE B6--continued

CONNECTIONS OF CONCRETE DIAPHRAGMS	
Inadequate in-plane shear transfer capacity	1. Reducing the local stresses at the diaphragm-to-wall interface by providing collector members or drag struts under the diaphragm and connecting them to the diaphragm and the wall. 2. Increasing the capacity of the existing diaphragm-to-wall connection by providing additional dowels grouted into drilled holes. 3. Reducing the shear stresses in the existing connection by providing supplemental vertical-resisting elements as discussed in Sec. 3.4.
Inadequate anchorage capacity for out-of-plane forces in the connecting walls	1. Increasing the capacity of the connection by providing additional dowels grouted into drilled holes. 2. Increasing the capacity of the connection by providing a new member above or below the slab connected to the slab with drilled and grouted bolts similar to that for providing a new diaphragm chord.
CONNECTIONS OF POURED GYPSUM DIAPHRAGMS	
Inadequate in-plane shear transfer Inadequate anchorage capacity for out-of-plane forces in the connecting walls	1. Providing new dowels from the diaphragm into the shear wall. 2. Removing the gypsum diaphragm and replacing it with steel decking. 3. Adding a new horizontal bracing system designed to resist all of the seismic forces.
CONNECTIONS OF PRECAST CONCRETE DIAPHRAGMS	
Inadequate in-plane shear transfer capacity Inadequate anchorage capacity at the exterior walls for out-of-plane forces	1. Increasing the capacity of the connection by providing additional welded inserts or dowels placed in drilled or grouted holes. 2. Increasing the capacity of the connection by providing a reinforced concrete overlay that is bonded to the precast units and anchored to the wall with additional dowels placed in drilled and grouted holes. 3. Reducing the forces at the connection by providing supplemental vertical-resisting elements as discussed in Sec. 3.4.

TABLE B6--continued

CONNECTIONS OF STEEL DECK DIAPHRAGMS WITHOUT CONCRETE FILL	
Inadequate in-plane shear capacity or anchorage capacity for out-of-plane forces in walls	1. Increasing the capacity of the connection by providing additional welding at the vertical element. 2. Increasing the capacity of the connection by providing additional anchor bolts. 3. Increasing the capacity of the connection by providing concrete fill over the deck with dowels grouted into holes drilled into the wall. 4. Increasing the capacity of the connection by providing new steel members to effect a direct transfer of diaphragm shears to a shear wall. 5. Reducing the local stresses by providing additional vertical-resisting elements such as shear walls, braced frames, or moment frames as discussed in Sec. 3.4.
CONNECTIONS OF STEEL DECK DIAPHRAGMS WITH CONCRETE FILL	
Inadequate in-plane shear capacity or anchorage capacity for out-of-plane forces in walls	1. Increasing the shear capacity by drilling holes through the concrete fill, and providing additional shear studs welded to the vertical elements through the decking. 2. Increasing the capacity of the connection by providing additional anchor bolts (drilled and grouted) connecting the steel support to the wall. 3. Increasing the capacity of the connection by placing dowels between the existing wall and diaphragm slab. 4. Reducing the local stresses by providing additional vertical-resisting elements such as shear walls, braced frames, or moment frames as discussed in Sec. 3.4.
CONNECTIONS OF HORIZONTAL STEEL BRACING	
Inadequate in-plane shear transfer capacity	1. Increasing the capacity by providing larger or more bolts or by welding. 2. Reducing the stresses by providing supplemental vertical-resisting elements such as shear walls or braced frames as discussed in Sec. 3.4.
Inadequate anchorage capacity when supporting concrete or masonry walls for out-of-plane forces	1. Increasing the capacity of the connection by providing additional anchor bolts grouted in drilled holes and by providing more bolts or welding to the bracing members.

TABLE B7
VERTICAL ELEMENT TO FOUNDATION CONNECTIONS

Deficiency	Strengthening Techniques
CONNECTIONS OF WOOD STUD SHEAR WALLS	
Inadequate shear capacity of the anchorage	1. Increasing the shear capacity by providing new or additional anchor bolts between the sill plate and the foundation. 2. Increasing the shear capacity by providing steel angles or plates with anchor bolts connecting them to the foundation and bolts or lag screws connecting them to the sill plate or wall.
Inadequate shear capacity of cripple stud walls	1. Adding plywood sheathing over the cripple studs (usually on the inside) by nailing into the floor framing and the sill plate. Anchorage of the sill plate to the foundation also must be provided.
Inadequate uplift capacity	1. Increasing the capacity by providing steel hold-downs bolted to the wall and anchored to the concrete. 2. Reducing the uplift requirement by providing supplemental shear walls as discussed in Sec. 3.4.
CONNECTIONS OF METAL STUD SHEAR WALLS	
Inadequate shear capacity of the anchorage	1. Provide anchor bolts, grouted in drilled holes, through sill plate of wall. 2. Provide steel angles with anchor bolts to concrete and bolts or screws to wall.
Inadequate shear capacity of cripple stud walls	1. Provide plywood sheathing, nailing into cripple studs, sill plate, and first floor framing; anchor sill plate to foundation.
Inadequate uplift capacity	1. Provide steel hold-down with bolts or screws to wall and anchor bolts to concrete at ends of shear wall. 2. Provide additional shear walls or vertical bracing.
CONNECTIONS OF PRECAST CONCRETE SHEAR WALLS	
Inadequate capacity to resist in-plane or out-of-plane shear forces	1. Increasing the capacity of the connection by providing a new steel member connecting the wall to the foundation or the ground floor slab. 2. Increasing the capacity of the connection by adding a new thickness of concrete (either cast-in-place or shotcrete) placed against the precast wall doweling into the existing foundation or ground floor slab.

TABLE B7--continued

CONNECTIONS OF PRECAST CONCRETE SHEAR WALLS--continued	
Inadequate hold-down capacity to resist seismic overturning forces	1. Increase the hold-down capacity by removing concrete at the edge of the precast unit to expose the reinforcement provide, new drilled and grouted dowels into the foundation, and pour a new concrete pilaster. 2. Reduce the uplift forces by providing supplemental vertical-resisting elements such as shear walls or braced frames as discussed in Sec. 3.4.
CONNECTIONS OF BRACED FRAMES	
Inadequate shear capacity	1. Increasing the capacity by providing new steel members welded to the braced frame base plates and anchored to the slab or foundation with drilled and grouted anchor bolts. 2. Reducing the shear loads by providing supplemental steel braced frames as discussed in Sec. 3.4.
Inadequate uplift resistance	1. Increasing the capacity by providing new steel members welded to the base plate and anchored to the existing foundation. 2. Reducing the uplift loads by providing supplemental steel braced frames as discussed in Sec. 3.4.
CONNECTIONS OF STEEL MOMENT FRAMES	
Inadequate shear capacity Inadequate flexural capacity Inadequate uplift capacity	1. Increasing the shear capacity by providing steel shear lugs welded to the base plate and embedded in the foundation. 2. Increasing the shear and tensile capacity by installing additional anchor bolts into the foundation. 3. Increasing the shear capacity by embedding the column in a reinforced concrete pedestal that is bonded or embedded into the existing slab or foundation.